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Population and diversity of earthworms in various vegetation types at the experimental garden of the Universitas Muhammadiyah Sumatera Utara Deli Serdang

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ABSTRACT

Earthworm diversity across different habitats serves as a key indicator of soil ecosystem health. Earthworms thrive only in environments that meet their specific needs, with vegetation being a crucial factor influencing their distribution. The diversity of plant species in an area can have a direct impact on earthworm biodiversity. This study aims to explore the effect of different vegetation types on earthworm diversity and its correlation with soil fertility at the experimental farm of Universitas Muhammadiyah Sumatera Utara. The research was conducted from December 2023 to March 2024. The equipment used included a 25x 25 x 30 cm quadrat frame, hoe, plastic bags, containers, tweezers, sample bottles, measuring tape, magnifying glass, microscope, lux meter, thermometer, hygrometer, soil tester, and coring tool. Materials used were 4% formalin, 70% alcohol, and distilled water. The survey method, with purposive sampling techniques, was employed, with predetermined sampling points. Earthworms were counted using the hand-sorting method, and identification was conducted up to the genus level using reference literature: Beddard (1912), Blakemore (2002), James and Wood (1993), Hong and James (2010), and Shen and Yeo (2005). Data were analyzed using scatter plots to examine distribution patterns, and correlation tests were performed to assess the relationship between earthworm diversity and soil chemical properties. The results showed that earthworm diversity in banana, sugarcane, and grass vegetation was categorized as low (H' < 1). An independent sample t-test revealed significant differences in earthworm diversity between banana and sugarcane vegetation compared to grass. Correlation tests indicated no significant relationship between diversity indices and soil moisture content, organic carbon, or pH levels.

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1. INTRODUCTION

Earthworms (*Oligochaeta*) play a crucial role in maintaining ecosystem balance in various regions of the world (Teng et al., 2013). As part of the low-stratified fauna in the Annelida group, earthworms are generally found in moist terrestrial habitats. Their existence is very beneficial for humans, both directly and indirectly, such as in the use of organic waste into fertilizers, sources of animal protein, and basic materials for medicines and cosmetics (Brata, 2010). Globally, earthworms play a role in improving soil porosity, facilitating water infiltration, and increasing nutrient availability for plants. Because of these functions, earthworms are often referred to as ecosystem engineers, which help accelerate nutrient cycling and support the decomposition of organic matter. Earthworm diversity usually varies depending on the type of land (Husamah et al., 2018).

Earthworm diversity in various habitats is the main indicator in assessing the health of soil ecosystems. Earthworms will only thrive properly if environmental conditions support their living needs. Many studies have revealed that factors such as vegetation growing on a land affect the diversity of earthworms (Aisyah et al., 2020). Each such vegetation produces a different volume and type of litter and will be the main source of energy for earthworms. The thickness of the litter covering the soil has an impact on the level of humidity and soil temperature which then affects the activity of soil organisms. This litter is the best food source for earthworms due to its high carbohydrate content and low levels of lignin and cellulose. However, earthworms cannot directly consume the newly fallen litter, because the litter needs to go through a decomposition process first before it can be eaten by earthworms (Dewi et al., 2006).

In the experimental garden of the University of Muhammadiyah North Sumatra, there are various kinds of vegetation, namely bananas, sugarcane and weeds. The variety of vegetation will have an impact on the quality in terms of soil physics and chemistry and will affect the diversity of earthworms (Sadewa et al., 2020). To find out the relationship between vegetation, soil quality, and earthworm diversity is complex. Some studies show that soils that are rich in organic matter and have a balanced pH tend to support better diversity of earthworm species.

Thus, this study aims to determine the influence of different vegetation on earthworm diversity and its correlation with soil fertility in the experimental garden of the University of Muhammadiyah North Sumatra. The results of this study are expected to provide deeper insights into the interactions between vegetation, soil quality, and earthworm diversity, as well as contribute to sustainable and environmentally friendly land management strategies. In addition, these findings can also be used as a basis for the development of better agricultural practices in the region, in order to improve soil fertility and ecosystem sustainability.

2. METHOD

This research was conducted at the Experimental Garden of the University of Muhammadiyah North Sumatra. The research was conducted in December 2023 - March 2024. The tools used are a square frame measuring 25 x 25 x 30 cm, hoes, plastic bags, plastic containers, tweezers, sample bottles, meters, lups, microscopes, luxmeters, thermometers, hygrometers, soiltesters and coring. The ingredients used are 4% formalin, 70% alcohol and aquades.

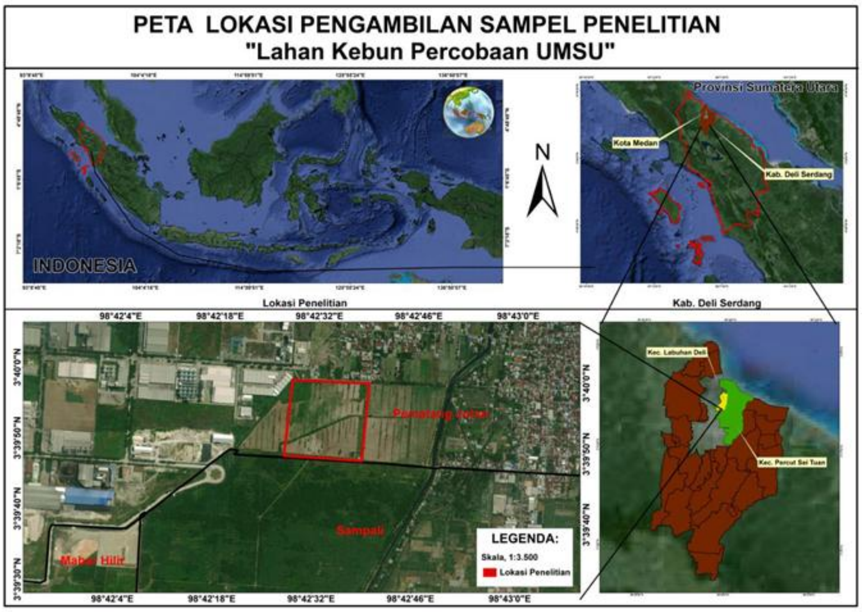

Figure 1. Map of the Research Location

This research was conducted at the Experimental Garden of the University of Muhammadiyah North Sumatra. The research was conducted in December 2023 - March 2024. The tools used are a square frame measuring 25 x 25 x 30 cm, hoes, plastic bags, plastic containers, tweezers, sample bottles, meters, lups, microscopes, luxmeters, thermometers, hygrometers, soiltesters and coring. The ingredients used are 4% formalin, 70% alcohol and aquades.

The method used in this study is to use a survey method with a purpose sampling technique whose sampling point has been predetermined. The method of calculating earthworms is using the *hand sorting method*. The collection of earthworm samples is taken to the laboratory to be identified with the help of a lup and a binocular microscope. Important characteristics used in the identification process include: number of segments, size, shape and color of the body; type of set; location and shape of the clitolium, tubercula puberty (TP) and genital tumescence (GT). Identification was carried out down to the genus level using reference literature: Beddard (1912); Blakemore (2002); James and Wood (1993); Hong and James (2010); Shen and Yeo (2005).

The data that has been obtained is analyzed using scatter plots to determine the distribution and a correlation test is carried out between the diversity of earthworms and the chemical properties of the soil so that conclusions are obtained that will represent the results of the research.

3. RESULTS AND DISCUSSION

This study was conducted to determine the population density and diversity of earthworms in three different types of vegetation, namely bananas (Musa sp.), sugarcane (Saccharum officinarum), and weeds (Imperata cylindrica), which are found in the experimental garden of the University of Muhammadiyah North Sumatra, Deli Serdang Regency. The analysis was carried out to see how each type of vegetation affects the abundance and diversity of earthworms as one of the indicators of soil biological health. The results of the identification and calculation of earthworm populations in the three types of vegetation are presented in Table 1 below:

Table 1. Population density and diversity of earthworms in various habitat types in the experimental garden of the University of Muhammadiyah North Sumatra (ind/m^2)

Taxis	Population Density (ind/m^2)		
	Banana	Sugar cane	Tares
Pontoscolex corethrurus	285,86	114,13	62,85
Pheretima Sp	225,06	74,66	56,72
Amynthas Sp	180,26	25,6	21,33
Total	691,18	214,39	140,9
Earthworm Diversity (H')	0,9038	0,8636	0,3906

Earthworms found in all three types of study habitats have varied compositions. The highest composition is found in the banana area and in the sugarcane area while the lowest is in the weed area (Table 1). Earthworms found in all three types of study habitats consist of two families represented by three genera. The family Glossoscolecidae is represented by the genus *Pontoscolex*, the family Megascolecidae is represented by the genera *Pheretima* and *Amynthas*. The diversity of earthworm species at the three study sites based on *the Shannon-Wienner* index (H') ranged from 0.3906–0.9038 (Table 1).

From table 1 we can see that earthworms with the genus *Colexpoints* dominating of the three habitat types. According to Suin (2012), the genus has a body length of 55-115 mm with a body diameter of 3.5-4 mm, and the number of segments is 190-209. It has a whitish-brown body color and the clitelum is located in segments 15-23 which thickens in the segments resembling a saddle, the spermateca holes there are three pairs located on 6/7 to 8/9, and the male genitalia are located on the 20/21 seta and can be located behind the clitol. *Colexpoints* It is an earthworm with an endogenous habitat type, which is an earthworm that feeds on a large amount of soil and organic matter in it, although the species sometimes appears to the surface in search of food. These worms form shallow, semi-permanent burrows. Endogeic earthworms have some pigmentation. Its muscular layer is not as thick and does not move as fast as an epigeic earthworm. Endogeic species have sizes ranging from 2.5–30 cm (Bouche, 1977).

In table 1, we can see that *Pontoscolex* dominates in three types of habitat areas because this worm is a earthworm that is tolerant of environmental conditions. *Pontoscolex* is a worm species that has wide adaptability, and is tolerant of various environmental conditions, so the worm has the potential to be developed as soil biotechnology in conservation and improving the fertility of tropical soils in Indonesia (Setyaningsih et al., 2014). According to Bansal et al., (2022) shows that this species is effective in decomposition organic matter and increasing nutrient availability for plants, especially in tropical soils that tend to have erosion problems and decreased fertility. Its strong adaptation to tropical soil conditions makes *Pontoscolex* a potential candidate for soil biotechnology programs, especially in the rehabilitation of degraded land. *Pontoscolex* has an important role in soil conservation in the tropics. Research by Fragoso et al., (2023) shows that *Pontoscolex* not only increases soil porosity through tunneling, but also plays a role in reducing surface flow and erosion, helping to maintain soil moisture and improve groundwater balance. This makes it a key species in efforts to improve the quality of tropical soils in Indonesia that are often degraded.

The highest diversity (H') of earthworms is in banana vegetation. According to Gamasika (2017) states that the environmental conditions around banana vegetation always support the growth of earthworms. The results of Maftuah's (2006) research show that earthworms like the area around banana plantations which have humid conditions and high moisture content, this is in accordance with the area around banana vegetation which has high humidity and moisture content. Research by Lavelle et al., (2022) supports this by mentioning that earthworms are more active and thrive in habitats that have sufficient moisture, as a humid environment increases their ability to move and dig tunnels. In addition, humid conditions support the process of decomposition of organic matter that is the main food source of earthworms Another study by Whalen and Sampedro (2020) also found that earthworms require high soil moisture content to support their physiological processes, such as skin respiration and excretion. A humid environment, such as that found around banana crops, allows earthworms to stay hydrated and maintain their biological activity. Sufficient moisture content also helps accelerate the decomposition of organic matter around plants, which is a major source of nutrients for earthworms. Furthermore, research by Jouquet et al., (2019) revealed that banana vegetation creates an ideal microhabitat for earthworms because in addition to providing moisture, banana plants also produce nutrient-rich organic litter. The decaying banana leaf litter provides the organic matter needed by earthworms for the decomposition process, thereby increasing their bioturbic activity which contributes to the improvement of soil structure.

The diversity of earthworms is higher in banana vegetation compared to sugarcane and weed vegetation is also suspected because earthworms have enough food on the vegetation. Areas with abundant organic matter are the cause of many worms in the area. According to Firmansyah & Yanti (2017), the diversity of earthworms can also be influenced by environmental conditions, including the physical condition of the soil (temperature, humidity, moisture content, soil texture), soil chemistry (pH, organic matter) and available foodstuffs.

Table 2. Independent sample t test on various habitat types in the experimental garden of the University of Muhammadiyah North Sumatra

Location Point	Sig. (2-tailed)
Bananas	0.487
Bananas	0.000
Sugarcane Weeds	0.001

(α = 5%; Sig. (2-tailed) < 0.05 = real difference; (2-tailed) > 0.05 = no real difference)

From the table above, there are three comparisons between sampling locations, namely between Bananas, Bananas, and Sugarcane. The significance value (Sig.) produced showed that there was a significant difference between the type of organic matter given at the location of Bananas and Weeds (p = 0.000) and between Sugarcane and Weeds (p = 0.001). However, there was no significant difference between Bananas and Sugarcane (p = 0.487).

The apparent differences in earthworm diversity between banana and weed habitats, as well as between sugarcane and weeds, are thought to be due to several important factors. One of the main factors is the composition of organic matter in each habitat. Weed habitats tend to have less land cover and are poor in organic matter. Another factor that can affect these differences is the structure and texture of the soil in each habitat. Weed habitats usually have a denser soil structure because there is no agricultural activity. Poor soil structure will cause limited movement space for earthworms (Raftullah, 2017). Earthworms generally prefer soils with non-dense structures because the high density of the soil inhibits their ability to move and form tunnels. Research shows that lower soil density facilitates the movement of earthworms through the soil because there are fewer mechanical obstacles they have to face. According to Binet et al., (2023) noted that earthworms, especially from anecdotal groups that form large macropores, are more effective at building channels on loose or well-structured soils. In dense soils, microporous predominates, preventing earthworms from moving freely, so their bioturbic activity decreases. Another study by Bhandari et al., (2023) shows that earthworms tend to be more active in soils with high porosity and adequate organic matter content, which is usually associated with looser, less dense soils. In looser soils, worms can tunnel more efficiently and facilitate water infiltration, increased soil aeration, and increased nutrient availability for plants. In contrast, dense soils limit their ability to do these things, which in turn can affect the overall structure of the soil. Research by Lee et al., (2023) also states that in soil with better structure, earthworms are able to create more tunnels that contribute to water flow and decomposition of organic matter. More dense soils reduce the effectiveness of these functions, which also limits other biotic activities that benefit soil ecosystems.

In table 2, it can be seen that the diversity of earthworms in banana and sugarcane vegetation is not significantly different. Table 1 actually shows that earthworm diversity tends to be higher in banana vegetation. This can be explained by the similarity of environmental conditions between the two vegetation. Banana and sugarcane vegetation have similar soil and microclimate characteristics, such as relatively stable humidity and a less dense soil structure, thus providing a comfortable habitat for earthworms to thrive (Salamah et al., 2016). In addition, the roots of the two vegetation also play a role in providing a good space for earthworms. The large, fibrous roots of bananas and sugarcane are able to improve soil structure by creating pores that facilitate the movement of earthworms, similar to the function that earthworms perform in increasing soil porosity. Thus, earthworms are comfortable living in these two habitats because they get similar support from the plants. According to the research of Zhang et al., (2021) stated that thickly fibrous roots in plants, such as sugarcane and bananas, are able to create macroporous pore spaces in the soil, which support water infiltration as well as air circulation. The structure of these formed pores is similar to that produced by earthworm activity, thus creating favorable conditions for their life and movement in the soil. In addition, Chagas et al., (2022) found that earthworms tend to inhabit soils with complex root systems, such as in bananas and sugarcane, as the roots of these plants also facilitate an increase in the content of organic matter in the soil. This accumulation of organic matter becomes a source of nutrients for earthworms and other soil organisms, improving the overall quality of the soil. The large, decomposed roots of these plants also serve as channels for earthworms to move more freely, avoiding the dense or consolidated soils that would normally hinder their movement. According to Wang et al., (2020) show that root structures can create pores in the soil that allow earthworms to move more freely, avoiding overcrowded or consolidated soils. Dense soils are often an obstacle to the movement of earthworms, which rely heavily on their ability to dig and adapt to environmental conditions. With plant roots that provide space for movement, earthworms can function more efficiently in soil ecosystems. On the other hand, research by Barros et al., (2021) revealed that healthy and thriving roots can contribute to increased earthworm activity, as they create a better environment for microbial life and other organisms in the soil. The presence of these microorganisms is essential in the process of decomposition and nutrient cycling, which helps to improve the overall quality of the soil.

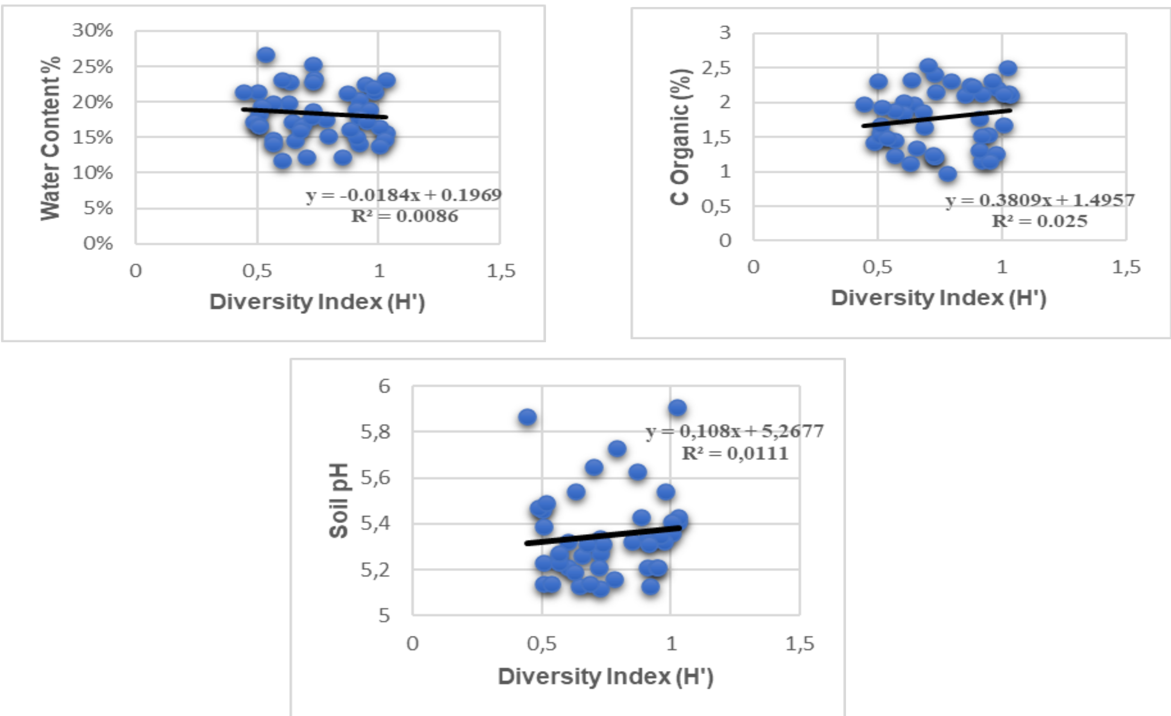

Figure 2. The relationship of diversity with soil moisture content, organic C and soil pH

The physical and chemical parameters observed in this study include moisture content, organic C, and soil pH. Physical and chemical parameters describe soil fertility conditions. In this study, there was no relationship between soil chemical conditions and earthworm diversity (Figure 2). There is no relationship between earthworm diversity and soil chemistry is suspected because the diversity index is low and the soil organic matter content is not very high. Organic matter is a food source for earthworms, but the availability in the soil in this study is low. The low content of organic matter is illustrated by the low diversity of earthworms. According to Coleman et al., (2020), earthworm diversity is often more influenced by the physical conditions of the soil, such as texture and structure, as well as by the amount of organic matter available. Low organic matter content, as illustrated in the results of this study, often leads to low diversity of earthworms, as organic matter is the main food source for them. In a study conducted by Fonte et al., (2019), soil organic matter is a key factor in supporting the existence and activity of earthworms. However, if the organic matter content is low, then the earthworm population tends to decline, as there is not enough food that can support their life. The low levels of organic matter in the soil observed in this study can lead to limited resources for earthworms, resulting in a low diversity index. This limited food source is also strengthened by research from Decaëns et al., (2018) who found that earthworm diversity is strongly related to the content of organic matter in the soil. In areas with low organic matter, especially in soils with intensive agricultural activities or in disturbed soils, earthworm diversity tends to be low due to nutrient limitations. In addition, if the soil is too acidic or too alkaline, this can inhibit the growth and activity of earthworms, but in these cases, pH does not show a significant influence, confirming that the content of organic matter is the main factor at play.

The acidity or alkalinity of the soil can have a significant impact on the growth and activity of earthworms. The average acidic pH in this study suggests that soil conditions may not be optimal for earthworm life. According to research by Van der Heijden et al., (2015) it is stated that low soil pH can inhibit the activity of earthworms, because worms prefer a neutral or slightly alkaline environment to maximize their metabolism and reproduction. Earthworms, especially species sensitive to acidity, may experience decreased population and activity in low pH conditions, leading to lower diversity within soil communities. Another study by Zangerl et al., (2020) suggests that too acidic soil pH can affect the availability of nutrients in the soil, especially essential elements such as calcium and magnesium. The limited availability of these nutrients can affect the quality of food available to earthworms, resulting in a low diversity of worms found at the study site. In situations where the pH is very acidic, earthworms may have to compete with other microorganisms that are more tolerant of acidity, which can reduce the worm's chances of multiplying and surviving. In addition, research by Ruan et al., (2018) found that pH variations within a given range can affect the stability of soil aggregates, which plays an important role in providing habitat for earthworms. In acidic soils, the stability of the aggregate may be compromised, affecting the physical quality of the soil and worm habitat. Poorer habitat quality can lead to low bioturbation activity and, in turn, affect the ecological processes associated with earthworm diversity.

Low soil pH can be closely related to moisture content, and this relationship affects soil fertility conditions and organisms' lives, including earthworms. When soil pH is acidic, chemical processes in the soil can affect the availability of water and nutrients available to plants and other organisms. According to research by Kiehl et al., (2017), acidic soils tend to have fewer important nutrients that are dissolved, such as calcium and magnesium, which can affect the soil's ability to hold water. The availability of these nutrients is important to help plants thrive properly and maintain proper moisture content in the soil. Furthermore, research by Zeng et al., (2021) shows that low pH is often accompanied by a decrease in cation exchange capacity (CEC) in the soil. The low cation exchange capacity means that the soil is less able to hold water and nutrients, so when the soil moisture content decreases, the soil becomes drier and cannot provide an optimal environment for soil organisms such as worms. Soil that is too acidic and dry can inhibit the activity of earthworms, who prefer moist conditions to survive and multiply On the other hand, sufficient moisture content can help neutralize the effects of low pH on the soil. Research by Borken et al., (2018) shows that by increasing water content, some of the negative effects of low pH can be minimized, as water serves as a solvent that helps in the mobilization and availability of nutrients for plants and other organisms. In this context, moisture content plays an important role in helping to support the presence and activity of earthworms even if the soil pH remains low. Soil moisture content is one of the important parameters that affect the diversity and activity of earthworms. In this study, high moisture content can create favorable conditions for earthworm life. According to Aira et al., (2020) earthworms need a humid environment to carry out bioturbation and growth activities. Sufficient moisture content not only provides an ideal habitat for earthworms, but also supports their movement and nutrition, as earthworms use water to aid in the process of digestion and absorption of nutrients from organic matter in the soil. Another study by Jastrow et al., (2021) shows that high moisture content can increase earthworm diversity, as certain worm species prefer humid environments. Earthworms that live in areas with high humidity can show better reproductive activity and faster growth, thus contributing to increased population and species diversity. In addition, the ideal moisture content can support a more efficient process of decomposition of organic matter, which in turn can provide more food sources for earthworms. However, it should be noted that too high a moisture content can also cause problems. According to Fragoso et al., (2021) stated that water-saturated soil conditions can result in a lack of oxygen in the soil, which can endanger the life of earthworms. In saturated conditions, earthworms may have difficulty breathing and can be at high risk of death. Therefore, it is important to achieve the right balance of moisture content to support earthworm health and diversity.

4. CONCLUSION

Based on the results of the study, the diversity of earthworms in banana, sugarcane and grass vegetation was low (H' < 1), with the genus Pontoscolex dominating, indicating a high adaptability to tropical environmental conditions. Banana vegetation had the highest diversity due to moister soil conditions and higher organic matter content compared to other vegetation. The t-test results show a significant difference between banana and sugarcane vegetation and grass, but there is no significant difference between banana and sugarcane. The correlation test shows that the diversity index is not related to soil moisture content, pH, and organic carbon, indicating that physical factors such as soil structure and porosity may have a greater influence on earthworm populations. For future research, it is recommended that a more in-depth analysis of soil physical parameters such as texture, soil temperature, and specific organic matter content be conducted, and that a longer observation period be involved to obtain a dynamic picture of earthworm populations in various ecosystem conditions and seasons.

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